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RHIC PROJECT

Brookhaven National Laboratory

Understanding the RHIC92 Dynamic Aperture

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1. Introduction

It has been pointed out by G.F. Dell[1] that the dynamic aperture of RHIC92 appears to be somewhat smaller than that of RHIC91. Tracking studies have been done to obtain some understanding of how the DO dipole affects the dynamic aperture in RHIC92.

Studies were done to find how large RDO, the coil radius of DO, has to be so Q2, Q3 are limiting the aperture and not DO. This result for RDO was found to depend on the value of β^*. For $\beta^* = 6$, this value of RDO is 5 cm; for $\beta^* = 2$, the value of RDO is 6.5 cm. This dependence of RDO on β^* would not be expected if the dynamic aperture scaled like the square root of beta.

Another factor that was studied is the role of the higher systematic multipoles like b_{12}, b_{14}, b_{16}, b_{18} in DO. A strong dependence on the higher systematic multipoles was found for $\beta^* = 6$ and RDO = 4 cm. However, the dependence on the higher systematic multipoles can be eliminated by increasing RDO to RDO $\geq$ 5 cm.

2. Dependence on Coil Radius, RDO

A tracking study was done to find how large RDO, the coil radius of DO, has to be so that Q2, Q3 are limiting the aperture and not DO, for the RHIC92 lattice. Figure 1 plots the dynamic aperture, A_{SL} versus RDO for two lattices. One lattice has 6 $\beta^* = 6$ insertions and the second has 6 $\beta^* = 2$ insertions. A_{SL} was found by tracking for 1000 turns for 10 different distributions of random field errors. The curve of A_{SL} vs. RDO levels off at a particular value of RDO where Q2, Q3 start to dominate. This occurs at RDO = 5 cm for the $\beta^* = 6$ lattice, and at RDO = 6.5 cm for the $\beta^* = 2$ lattice. One may note, that A_{SL} for $\beta^* = 2$ at smaller RDO, RDO $\leq$ 5 cm, is about 25% smaller than what one would expect from scaling the A_{SL} at $\beta^* = 6$ by the square root of the beta functions. At higher RDO, where the curves have leveled off, the A_{SL} do about scale like $\beta^{1/2}$.

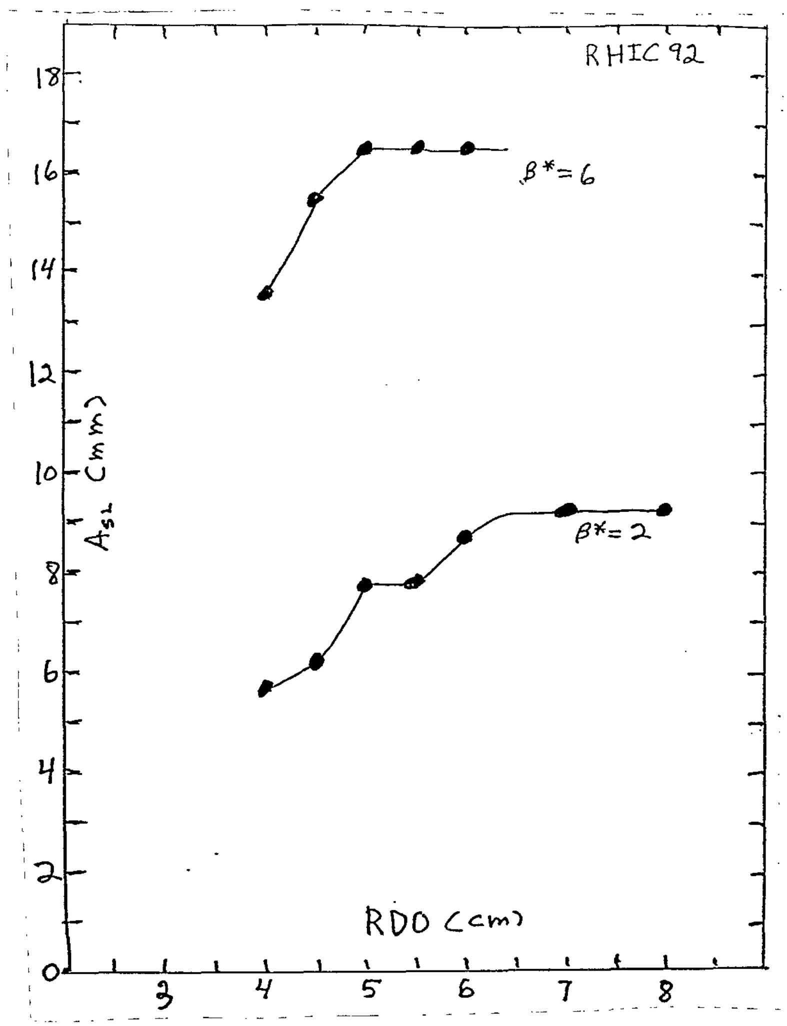

Fig. 1. A_{SL} versus RDO.

3. The Role of the Higher Systematic Multipoles in DO

Because the beta function at DO is about 10% higher than it was in RHIC91, the dynamic aperture may be becoming sensitive to the higher systematic multipoles b_{12}, b_{14}, b_{16}, b_{18}, etc. It has been pointed out[2] that these higher systematic multipoles can get to be several hundred times larger than the corresponding random field multipoles, and may affect the dynamic aperture. This is particularly true in a magnet with a high beta function. I think that it is undesirable that the dynamic aperture depend on the higher systematic multipoles. Not much is known just now about these multipoles, as to their magnitude or as to how sensitive they may be to the construction procedure. The b_{12}, b_{14}, b_{16}, b_{18} used in this study were computed by P. Thompson some years ago.

Figure 2 plots A_{SL} against $k_{s,\max}$, where $k_{s,\max}$ is the highest systematic multipole present in DO. Results are shown for $\beta^* = 6$ and $\beta^* = 2$ and for several values of RDO. For a particular value of $k_{s,\max}$, all systematic multipoles up to $k_{s,\max}$ are present. One may note that the strong dependence on $k_{s,\max}$ is found for $\beta^* = 6$ lattice for RDO $= 4$ cm. This dependence on $k_{s,\max}$ disappears for RDO ≥ 5 cm. The $\beta^* = 2$ lattice does not show much dependence on $k_{s,\max}$. This may be due to the A_{SL} for $\beta^* = 2$ being about 25% smaller than the result found by scaling the A_{SL} for $\beta^* = 6$ like $\beta^{1/2}$. The above effect may be used as an additional argument for choosing RDO ≥ 5 cm.

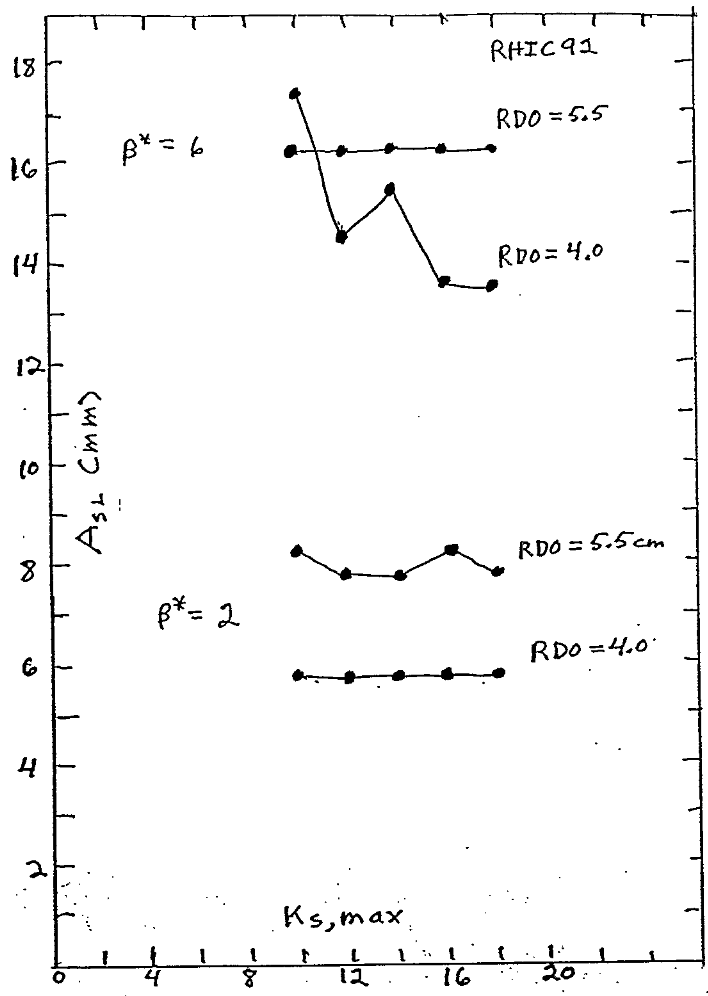

Fig. 2. $A_{S,L}$ verus $k_{s,\max}$

4. Improving the RHIC92 Dynamic Aperture

Figure 1 shows that the dynamic aperture for RHIC92 is 7.8 mm for $\beta^* = 2$ and RDO = 5.5 cm. This is about the same A_{SL} that RHIC91 had for RDO = 4 cm. Can the A_{SL} for RHIC92 be improved? One can attempt to answer the question using the results in Fig. 1 and a certain model for the dynamic aperture. The model I propose to use is that the dynamic aperture is dominated by one type of magnet like DO or Q2, Q3, and the dynamic aperture scales like the square root of the beta function. This model is known to be not quite correct, so the conclusions reached below should be regarded with suspicion.

1. Decrease the beta functions at Q2, Q3. According to Fig. 1, A_{SL} is dominated by the DO magnet at RDO = 5.5 cm. Thus this suggestion should not change A_{SL}.
2. Move DO back to where it was in RHIC91. This reduces the beta function at DO by 10% and increases A_{SL} by 5%. However RDO is now limited to 4.5 cms (H. Hahn), and according to Fig. 1 reducing RDO from 5.5 to 4.5 reduces A_{SL} by 20% for $\beta^* = 2$. Thus this suggestion decreases the A_{SL}.
3. A suggestion that would increase A_{SL} is to increase RDO from RDO = 5.5 to RDO = 6.5. This would increase A_{SL} from 7.8 mm to 9.2 mm for $\beta^* = 2$. However this further increase in RDO is probably not possible.

Based on this model, all the above apparent suggestions for improving the RHIC92 aperture do not appear to be workable.

5. Comparison of RHIC91 and RHIC92

It was noted by G.F. Dell[2] that the dynamic aperture of RHIC92 appears to be somewhat smaller than that of RHIC91. A comparison of the results for A_{SL} for these two lattices are given in Table 1. These results are in reasonable agreement with the results of G.F. Dell.

Table 1: Comparison of A_{SL} for the RHIC92 and RHIC91 Lattices.

	$\beta^* = 2$		$\beta^* = 6$	
	RDO = 4	RDO = 5	RDO = 4	RDO = 5
RHIC92	5.8	7.8	13.5	16.5
RHIC91	7.2	9.2	15.5	17.5

The largest apparent factor in the loss of dynamic aperture for RHIC92 is the higher β function by 10% at DO. This would account for a loss of 5% compared to the 15% loss observed for $\beta^* = 2$, RDO = 5. Even larger losses are observed for other β^* and RDO. So far, the loss in aperture is difficult to understand.

References

1. G.F. Dell, Comparison of Apertures for RHIC91 and RHIC92 at $\beta^* = 6$ m, AD/RHIC/AP-90 (1992).
2. G. Parzen, Higher Order Multipoles – Aperture and Tracking Studies, RHIC/AP-25 (1986).